SIMULATED EFFECTS OF AN ARTIFICIAL-RECHARGE EXPERIMENT NEAR PROCTOR, LOGAN COUNTY, COLORADO

By Alan W. Burns

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 84-4010

Prepared in cooperation with the

COLORADO DIVISION OF WILDLIFE

DEPARTMENT OF NATURAL RESOURCES

Lakewood, Colorado
1984

UNITED STATES DEPARTMENT OF THE INTERIOR

WILLIAM P. CLARK, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

Colorado District Chief
U.S. Geological Survey, MS 415
Box 25046, Denver Federal Center
Lakewood, CO 80225

For sale by:

Open-File Services Section
Western Distribution Branch
U.S. Geological Survey, MS 306
Box 25425, Denver Federal Center
Denver, CO 80225
(303) 236-7476

CONTENTS

	Page
Abstract	1
Introduction	1
Setting	2
Recharge Experiment	4
Operation	4
Data collection and results	4
Interpretation	7
Simulation model	7
Assumptions	7
Calibration	8
Simulated effect of the recharge experiment on the South Platte River	8
References	13
Supplemental information	15

ILLUSTRATIONS

	Page
Figure 1. Map showing location of study area	3
2-6. Graphs showing:	
2. Observed and computed water levels at observation well 3	9
3. Observed and computed water levels at stock well 719	10
4. Observed water levels in stock wells 702 and 741	11
5. Stream accretion and depletion due to one 4-month recharge period	12
6. Stream accretion and depletion due to cyclic 4-month recharge periods	14

TABLES

	Page
Table 1. Flow-meter readings, estimated pumping rates, and operating data	5
2. Depth to water in wells measured during the recharge experiment	6
3. Driller's logs of four observation wells	17

METRIC CONVERSION FACTORS

Inch-pound units in this report may be expressed as International System of Units (SI) by use of the following conversion factors:

Multiply	*By*	*To obtain*
acre	0.4047	hectare
acre-foot (acre-ft)	0.001233	cubic hectometer
cubic foot (ft^3)	0.02832	cubic meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
foot per day (ft/d)	0.3048	meter per day
gallon (gal)	3.785	liter
gallon per minute (gal/min)	0.00006309	cubic meter per second
inch (in.)	25.40	millimeter
inch per hour (in/h)	25.40	millimeter per hour
micromho per centimeter at 25°C	1.0000	microsiemens per centimeter at 25°C
mile (mi)	1.609	kilometer
square foot (ft^2)	0.09294	square meter

SIMULATED EFFECTS OF AN ARTIFICIAL-RECHARGE EXPERIMENT NEAR PROCTOR, LOGAN COUNTY, COLORADO

By Alan W. Burns

ABSTRACT

Data were collected on an artificial-recharge experiment near Proctor, Colo., as part of an effort to document the effects of artificial recharge in the South Platte River valley. A computed 620 acre-feet were pumped from a well during a 4-month period. A computed 420 acre-feet were delivered at the potential reservoir site, and the remaining 200 acre-feet leaked from the pipeline. No pond was created at the recharge site due to the high rates of infiltration. Water levels in the nearest well (about 0.1 mile from the recharge site) rose almost 25 feet.

Computer simulations indicate that this 4-month pumping-recharge experiment would cause large initial stream depletions from the nearby South Platte River for the first 16 months; thereafter, stream accretions due to the recharge would exceed stream depletions due to pumpage. The net accretion would be at a lesser rate than the initial stream depletion. If the experiment were conducted annually, the simulations indicate that stream depletions would occur for 6 months of each year and stream accretions for the remaining 6 months once the stream reached an equilibrium condition. To reach the cyclic equilibrium condition would take at least 7 years.

INTRODUCTION

Artificial recharge of the alluvial aquifer system adjacent to the South Platte River is a water-management activity being used more and more in Colorado. Artificial recharge may be used to serve two purposes: (1) to store water underground as an alternative to surface storage during the nonirrigation season; and (2) as a realistic mechanism for ground-water irrigators to satisfy their legal obligations in the form of plans of augmentation. Little data exist within the South Platte River valley to document the effects of artificial recharge. Recharge studies have been conducted in Prospect Valley, a tributary valley to the South Platte River by Skinner (1963) and the South Platte Ditch near Prewitt Reservoir by Lee and others (1980).

During the spring of 1979, the Lower South Platte Water Conservancy District requested the U.S. Geological Survey, Water Resources Division, Colorado District, to prepare a project proposal to monitor and evaluate a proposed artificial recharge project in the sandhills south of the South Platte River downstream from Sterling, Colo. Although no firm plans had been made, about 15 potential reservoir sites had been delineated at depressions in the sandhills. It was proposed to fill these reservoirs from either winter surface-water diversions or winter pumpage of ground water from the valley alluvium. Although the project has not yet been undertaken, it does illustrate the interest in such projects.

In September 1979, Mr. Maynard Sonnenberg, landowner and Director of the Lower South Platte Water Conservancy District, informed the U.S. Geological Survey that he would be conducting a recharge test at one of the potential recharge sites near an ongoing project funded cooperatively by the U.S. Geological Survey and the Colorado Division of Wildlife at Tamarack Ranch Wildlife Area. Because of the proximity of the two sites (about 8 mi), hydrologic similarities, and similar potential water management activities, it was determined that any data collected during Sonnenberg's recharge experiment and the evaluation of that data would also benefit the Colorado Division of Wildlife in managing the water resources of Tamarack Ranch Wildlife Area. Thus, all of the data were collected during routine field trips to the Tamarack Ranch Wildlife Area.

The purpose of this report is to present the data collected during the recharge experiment and to simulate the effects of the experiment on the South Platte River. The author wishes to acknowledge the permission, cooperation, and assistance of Mr. Sonnenberg and his foreman, Mr. Kenneth Crandall.

SETTING

The site of the artificial recharge experiment is about 1 mi west of the Proctor exit on Interstate Highway 76 in Logan County, Colo. The locations of the pumping well, observation wells, and the site of the potential recharge reservoir are shown in figure 1. After delineating the potential reservoir site, Mr. Sonnenberg had observation wells 1, 2, 3, and 4 installed along the edge of the potential reservoir. The wells were drilled through the eolian sands and alluvial sands and gravels (see table 3 in the Supplemental Information Section) into the underlying Brule Formation of Oligocene age (see Bjorklund and Brown, 1957, pages 15-33), which acts as the impermeable base of the alluvial aquifer system. The observation wells were finished with 4-in slotted plastic casing throughout their depths. Along the south side of Interstate Highway 76 are three stock wells, two abandoned (702 and 741) and the other (719) turned off during the entire experiment. An abandoned stock well (722) about 2,000 ft north of the pumping well also was monitored.

The pumping well is normally used with a center pivot sprinkler to irrigate about 160 acres. An 8-in. irrigation pipeline was laid over a distance of about 1 mi. The pipeline went through an underpass of Interstate Highway 76 and extended southward over the crest of a hill about 50 ft. From there, the water could run downhill about 200 ft into a small depression. Once that depression filled with water it would spill over into other depressions comprising the potential reservoir.

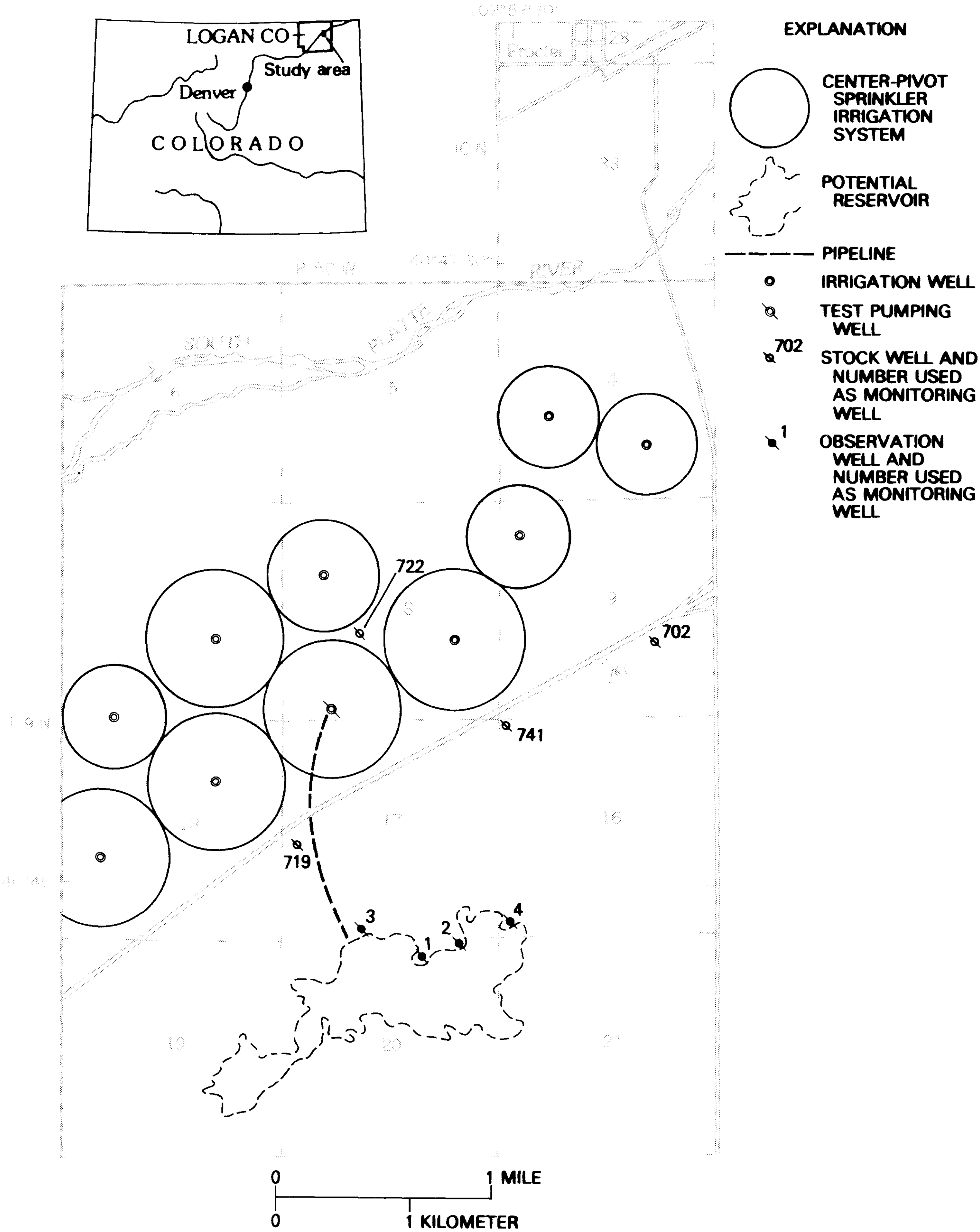

Figure 1.--Map showing location of study area.

RECHARGE EXPERIMENT

Operation

The well pump was started on Oct. 29, 1979, and ran more or less continuously from that time until Feb. 29, 1980. Occasional shutdowns were due to various mechanical and electrical problems. Flow meter readings, estimated pumping rates, and operating data are listed in table 1. Total pumpage from the well during the 4-month period was computed to be about 620 acre-ft. After an estimated flow measurement at the terminal end of the discharge pipe indicated that only about 65 percent of the pumped water was being delivered, a flow meter was installed at the discharge point and leakage along the discharge line was reduced. The total discharge at the terminal point was computed to be about 420 acre-ft during the 4-month period.

Data Collection and Results

One of the more interesting results of this experiment was that there was no ponding of water in the reservoir site. The discharge pipe terminated about 200 ft up a slightly graded hill from a minor depression. The water ran out the discharge pipe, onto the ground, and downgradient toward the bottom of the depression. Before traveling the 200-ft distance to the base of the depression, the water had completely infiltrated into the sandy soil (classified as Valent sand with permeability rates of 5 to 10 in/hr by the U.S. Department of Agriculture, Soil Conservation Service, 1974). Thus, all of the recharge occurred along the pipeline where it leaked and near its terminal point, rather than over the area of the potential reservoir site.

Water levels were measured before, during, and after the experiment to monitor the impact of the artificial recharge on the alluvial aquifer system. Depths to water in wells and the dates measured are shown in table 2. Significant rises in water levels took place at the observation well nearest the terminal point of the discharge pipeline (about 25 ft at well 3) and at the stock well nearest the pipeline (about 8 ft at well 719). It should be noted that the static water level in the pumped well was about 4 ft higher 1 month after the test than prior to the test.

After the Mar. 18, 1980, measurements were made, observation well 3 was bailed. Approximately 25 gal were bailed from the well in about a 10-minute period. This withdrawal caused a drawdown of about 6.7 ft. The water level recovered to within 0.2 ft of the static level in a 1-hour period. This confirms there was water stored in the sands and gravels above the Brule Formation in the vicinity of observation well 3 but there were not sufficient measurements nor accurate bailings to compute a transmissivity value.

Table 1.--*Flow-meter readings, estimated pumping rates, and operating data*

Date	Meter reading (acre-feet)	Observed pumping rate (gallons per minute)	Volume pumped during interval (acre-feet)	Estimated average pumping rate (gallons per minute)	Computed hours of operation	Elapsed hours	Percent of time in operation	Discharge pipe meter reading	Discharge pipe observed flow rate (gallons per minute)	Volume discharged during interval (acre-feet)	Percent of pumpage discharged
1979											
Oct. 12	51.505	Off	-------	-----	-----	---	---	-------	-----	--------	--
Oct. 29	51.578	Off	-------	-----	-----	---	---	-------	-----	--------	--
Oct. 31	52.234	-----	0.656	1,070	3.3	7	---	-------	-----	[1]0.4	65
Nov. 8	90.788	1,070	38.554	1,070	195.7	192	102	-------	-----	[1]5.1	65
Nov. 12	109.907	-----	19.119	1,090	95.3	96	99	-------	-----	[1]12.4	65
Nov. 14	119.224	1,090	9.317	1,090	46.4	48	97	-------	[2]625	[1]6.1	65
Nov. 17	304.045	1,270	184.821	1,270	790.3	792	100	-------	-----	[1]120.1	65
1980											
Jan. 2	394.037	-----	89.992	1,270	384.8	384	100	-------	-----	[1]58.5	65
Jan. 16	458.406	Off	64.369	1,270	275.3	336	02	-------	-----	[1]41.8	65
Jan. 18	[3]458.406	-----	0	-----	0	---	---	0.000	-----	--------	--
Jan. 20	[3]458.406	-----	[1]14.4	1,300	60.2	48	125	10.099	1,010	10.099	70
Feb. 2	[3]458.406	-----	[1]71.5	1,300	298.7	312	96	63.723	-----	53.624	75
Feb. 6	[3]458.406	1,275	0	-----	0	96	0	63.723	930	0	--
Feb. 14	504.883	1,200	46.477	1,300	194.2	192	101	97.131	950	33.408	72
Feb. 18	526.034	1,200	21.151	1,300	88.4	96	92	112.365	940	15.234	72
Feb. 25	568.201	1,160	42.167	1,300	176.2	168	105	141.766	820	29.401	70
Feb. 28	584.579	Off	16.378	1,300	68.4	72	95	152.615	Off	10.849	66
TOTAL			618.9							417.0	

[1]Estimated.
[2]Field measurement.
[3]Meter was temporarily broken.

Table 2.--*Depth to water in wells measured during the recharge experiment*

[All water levels are in feet]

Date	Pumping well	Stock wells				Observation wells			
		722	702	742	719	3	1	2	4
1979									
Oct. 12	81.07	-----	69.85	80.86	95.42	-------	-------	-------	-------
Oct. 29	-----	-----	-----	-----	-----	107.69	111.39	-------	-------
Nov. 8	-----	38.64	69.80	-----	95.45	106.96	111.40	104.01	101.82
Nov. 14	-----	-----	-----	80.52	-----	[1]106.6	[1]111.5	[1]104.0	[1]101.9
Dec. 8	-----	-----	69.66	80.13	92.53	[1]94.5	[1]111.4	-------	-------
1980									
Jan. 15	-----	-----	-----	-----	-----	[2]89.1	[2]111.6	-------	-------
Jan. 16	-----	38.39	69.35	79.76	88.65	-------	-------	-------	-------
Feb. 14	-----	38.01	-----	-----	88.16	[1]86.1	-------	-------	-------
Feb. 25	-----	-----	-----	-----	-----	[2]83.9	-------	-------	-------
Feb. 28	-----	-----	-----	-----	-----	[2]83.4	-------	-------	-------
Mar. 6	-----	-----	-----	-----	-----	[2]83.9	[2]111.3	[2]104.4	-------
Mar. 17	-----	-----	-----	-----	-----	[2]83.9	[2]111.4	[2]104.0	-------
Mar. 18	78.12	87.19	68.78	79.30	86.98	84.18	111.41	104.09	101.90
Mar. 19	-----	-----	-----	-----	-----	[2]84.4	-------	-------	-------
Apr. 17	77.10	36.45	68.55	78.96	86.92	87.10	111.42	-------	-------
July 2	-----	-----	67.86	78.52	86.80	90.90	-------	-------	-------

[1]Reading was taken with an electrical tape and adjusted 1.0 foot to equate the reading with that taken with a steel tape.

[2]Reading was taken with an electrical tape and reported by the owner (readings adjusted +0.4 foot based on readings taken Mar. 17, Mar. 18, and Mar. 19.

A minimal amount of water-quality data were collected. On Feb. 14, 1980, the temperature of water discharging from the pipeline at its terminal point was 13°C, with a specific conductance of about 500 micromhos per centimeter at 25°C. These readings probably are representative of the discharged water throughout the experiment. Water collected from observation well 3 on Feb. 14, 1980, had a temperature of 14°C and a specific conductance of about 150 micromhos. This sample probably represents the naturally occurring water in the sandhills (samples from a similar setting 10 mi east have a specific conductance of about 250 micromhos). The sample collected on Mar. 18, 1980, from observation well 3 had a temperature of 14°C and a specific conductance of about 200 micromhos.

Interpretation

The water-level rises observed in observation well 3 and stock well 719 were direct results of the artificial recharge. Interpretation of those rises will be discussed later in the next section. The approximate 4-ft rise in the pumped well and the 2-ft rise in the nearby stock well 722 are assumed to be caused by the general recovery that occurs naturally each spring and the recovery of water levels after cessation of summertime pumping in several nearby irrigation wells. Water levels in stock wells 741 and 702 rose about 2 ft during the monitoring period. This is thought to be a part of the natural seasonal fluctuation (the average increase of water levels of five wells just south of Interstate Highway 76, 10 mi east in similar topographic settings, was about 1 ft). Some of this rise also might be due to the recovery of water levels after cessation of pumping for summer irrigation in a well 0.5 mi north.

The water levels in observation wells 1, 2, and 4 did not change during the entire test. This fact, plus the information from the driller that he bailed the holes dry (Harold Canfield, Fort Morgan, Colo., written commun., 1979), implies that the water levels in those wells represent the top of the Brule Formation where the small amount of naturally occurring water in the sand and gravels has filled the "hole" in the relatively impermeable silts of the Brule Formation. Thus, the alluvial (or eolian) sands and alluvial gravels in this area are assumed to have been unsaturated prior to the recharge experiment. The water that infiltrated the soils during the recharge test did not travel far enough to reach these three wells.

SIMULATION MODEL

Assumptions

To analyze the results of the recharge experiment, using the responses in observation well 3 and stock well 719, a digital-computer ground-water flow model (Trescott, 1973) was used. Analytical techniques to evaluate recharge in a previously unsaturated porous media are not available; thus the model was required. The modeled area extended from the South Platte River (assumed to be a constant-head boundary) to about 2,000 ft south of the terminal point of the discharge pipeline. Aquifer characteristics between the South Platte River and approximately Interstate Highway 76 were taken from published maps (Hurr and others, 1972). The assumed unsaturated areas in the vicinity of the recharge were initially simulated with a minimal saturated thickness to allow model computations. The model was a difference model, assuming a flat water table so the unknown stresses would not complicate the analysis. When modeling only the impact of the pumped well and subsequent recharge, this assumption is justified. (See the section "Technical Discussion of Ground-Water Modeling" at the end of report for further discussion.)

Calibration

The hydraulic conductivity and specific yield of the sands and gravels above the bedrock in the recharge area were estimated by simulating the response of the observation wells to the applied recharge. During this simulation, the pumping well was ignored because of the unknown stresses acting on the system that caused the static water level in the pumping well to rise and because the recharge area is assumed to be initially unsaturated. The recharge was simulated at a rate of 1.74 ft^3/s (414 acre-ft for 120 days) and assumed to occur over an area of 2,500 ft^2. Observation well 3 was a little more than 0.1 mi from the terminal point of the discharge pipeline, but the actual distance to the point of recharge at the phreatic surface is unmeasurable. The model was used to simulate water-level rises due to the artifical recharge for various combinations of distance, specific yield, and hydraulic conductivity. Figure 2 shows the measured rise in water levels at observation well 3 and the computed water-level rises at various distances, specific yields, and hydraulic conductivities. Changing hydraulic conductivity or specific yield by about 50 percent resulted in distinctly different curves. Computed water-level rises best fit the observed water-level rise when $r = 629$ ft, $S = 0.15$, and $K = 60$ ft/d (see fig. 2).

The water levels at stock well 719, estimated to be 1,600 ft from the discharge terminal point, was simulated lower than the observed water levels. The greater observed water-level rise is hypothesized to be caused by recharge due to leakage along the pipeline. Therefore, the simulated conditions were modified, distributing linearly along the pipeline as recharge the remaining 0.84 ft^3/s (200 acre-ft for the 120 days) that was pumped. Results from this simulation were better (fig. 3) but still too low. The simulated data were adjusted by 1 ft to account for the rise observed in stock wells 741 and 702 which were not affected by the artificial recharge (see fig. 4). This correction shows how the model simulation could have been improved if the causes of the regional recharge were understood and could be modeled. Figures 2 and 3 would seem to substantiate that the hydraulic properties used in the model are reasonable.

SIMULATED EFFECT OF THE RECHARGE EXPERIMENT ON THE SOUTH PLATTE RIVER

Using the calibrated ground-water model, the effect of the pumping well and the recharge on the streamflow of the South Platte River was simulated. The situation was modeled for 5 years with the pumping well discharging at a rate of 2.58 ft^3/s for the first 120 days, a total of 26.7 million ft^3 (614 acre-ft). A second simulation assumed that recharge occurred at the same rate for the same 120 days. The simulated depletion of streamflow in the river due to the pumping for the first simulation and the simulated accretion of streamflow in the river due to the artificial recharge for the second simulation for one 4-month period are shown in figure 5. Superimposing these two results indicates that the streamflow of the river would be depleted for the first 16 months after the beginning of the test but that streamflow accretion due to artificial recharge would exceed losses due to pumpage from that time on. Nearly 100 percent of the volume pumped would have depleted streamflow within 5 years and about 75 percent of the recharge would have augmented streamflow. Thus the net loss to the river after 5 years would still be about 25 percent of the pumpage.

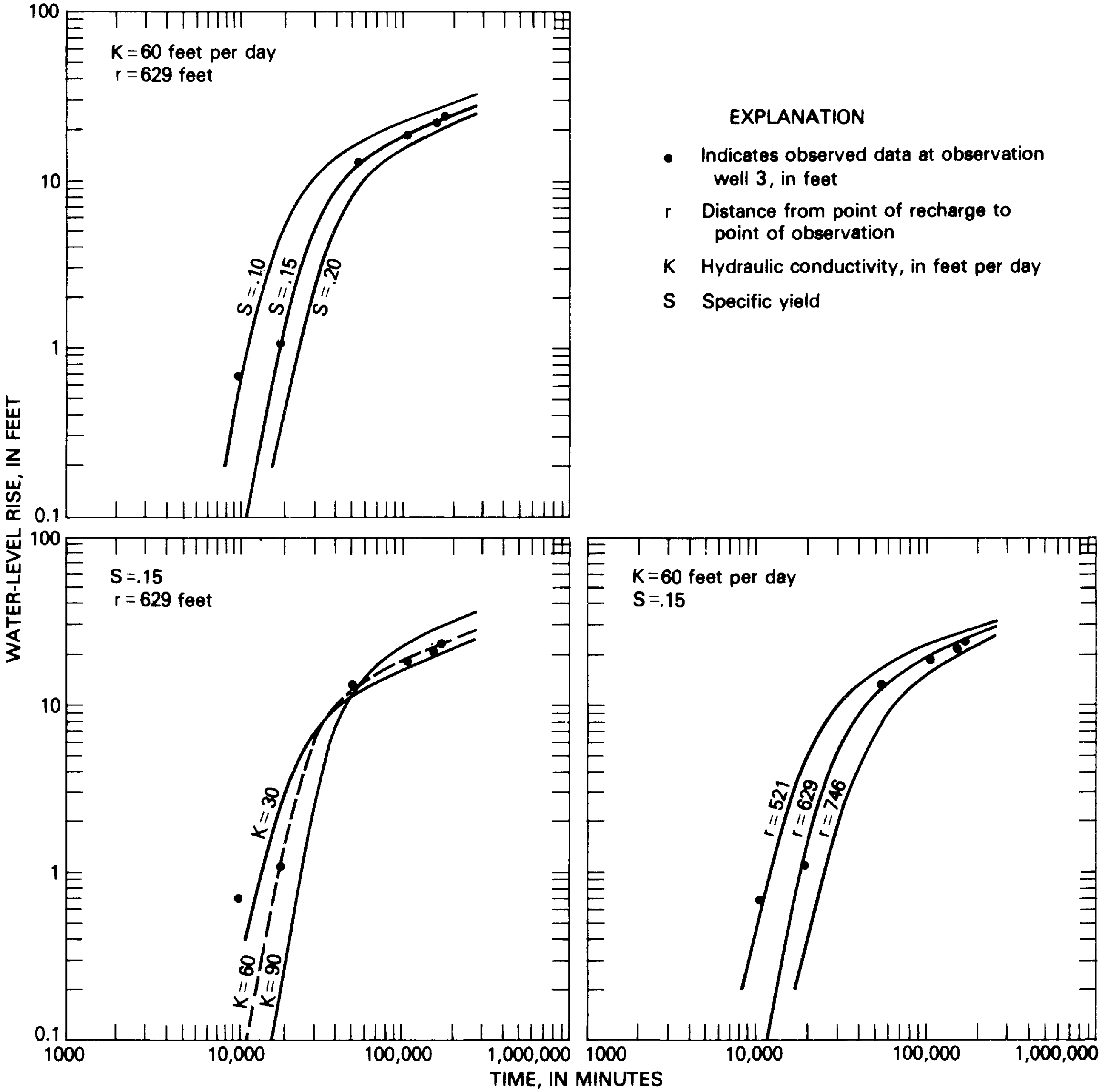

Figure 2.--Observed and computed water levels at observation well 3.

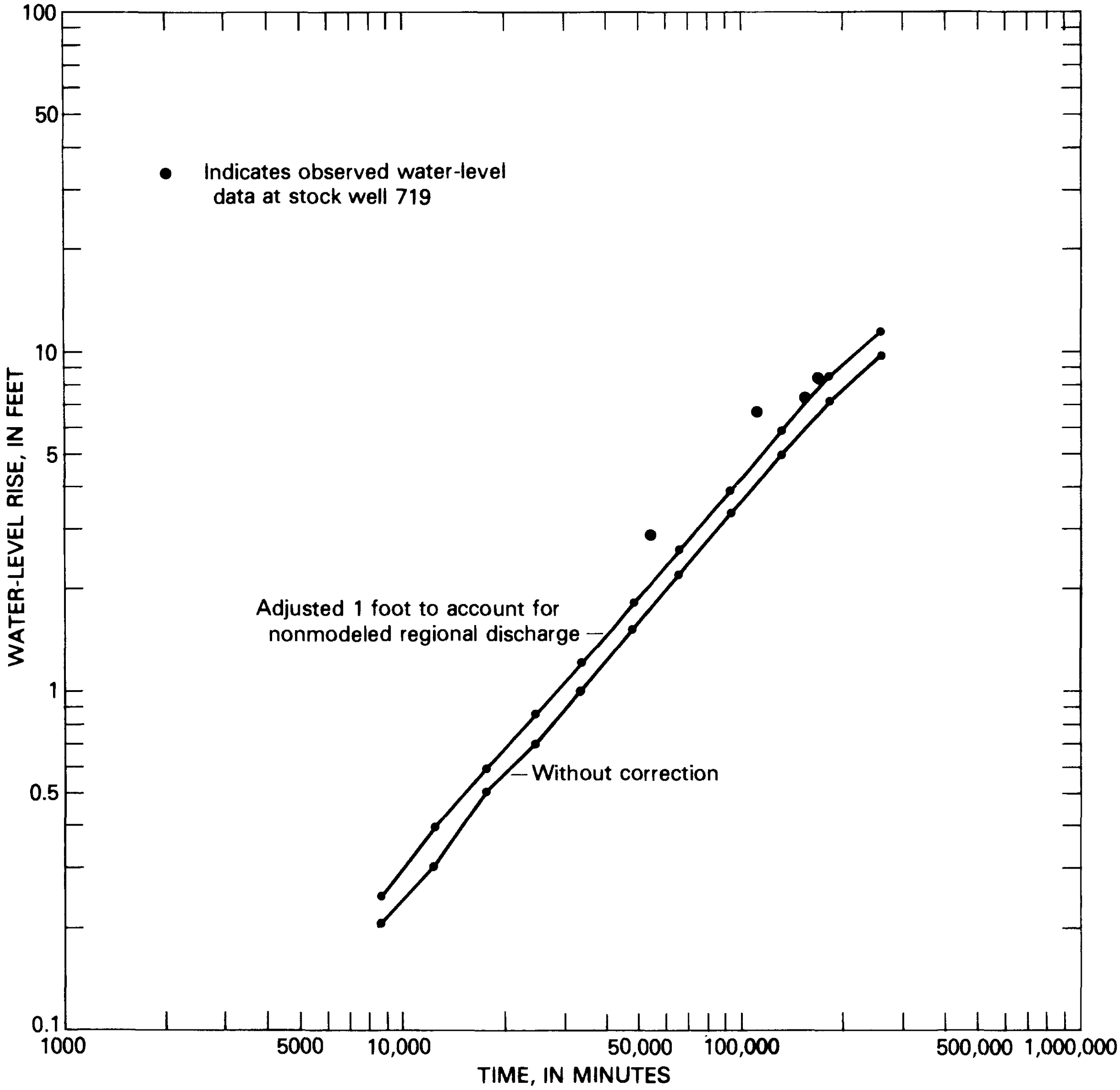

Figure 3.--Observed and computed water levels at stock well 719.

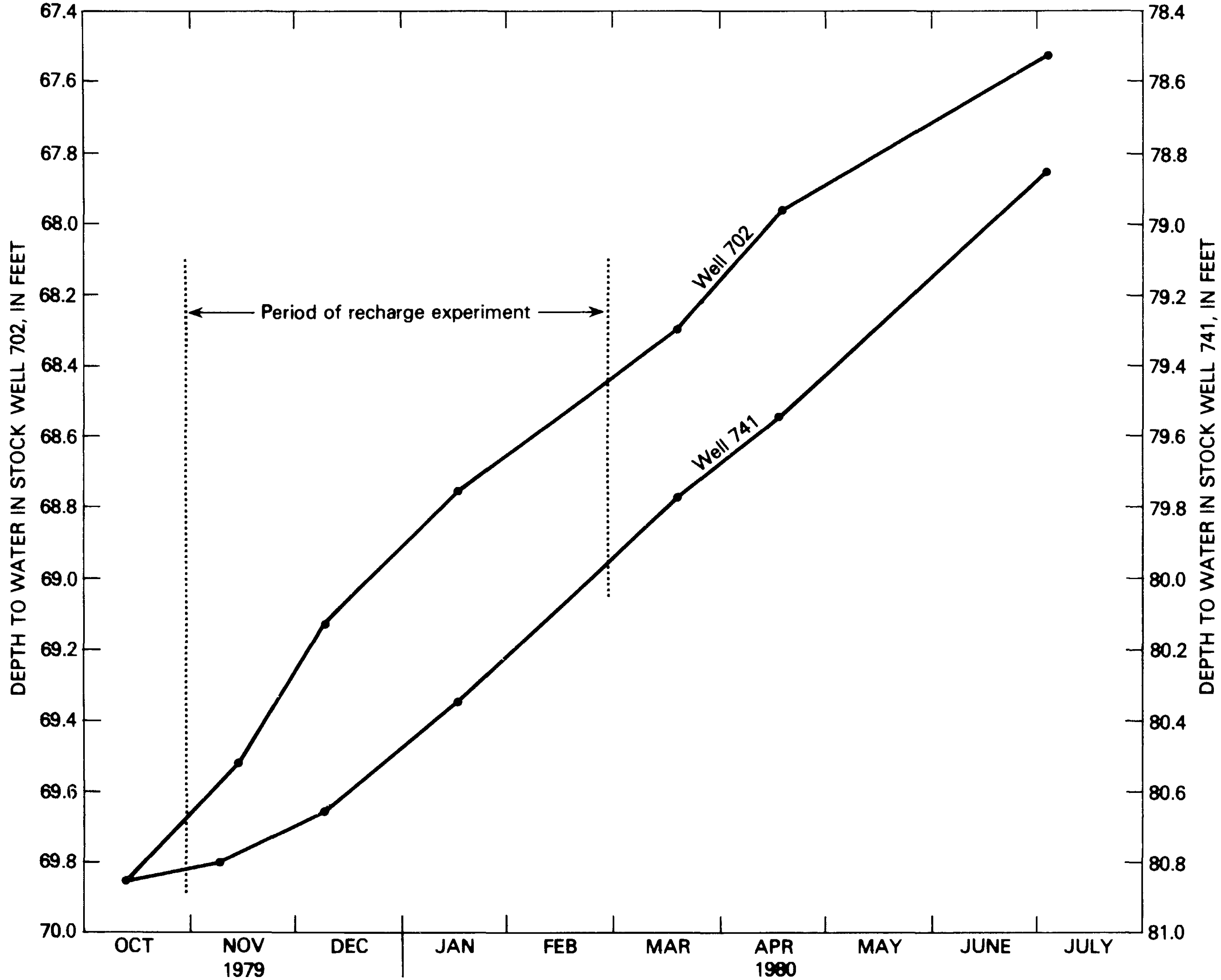

Figure 4.--Observed water levels in stock wells 702 and 741.

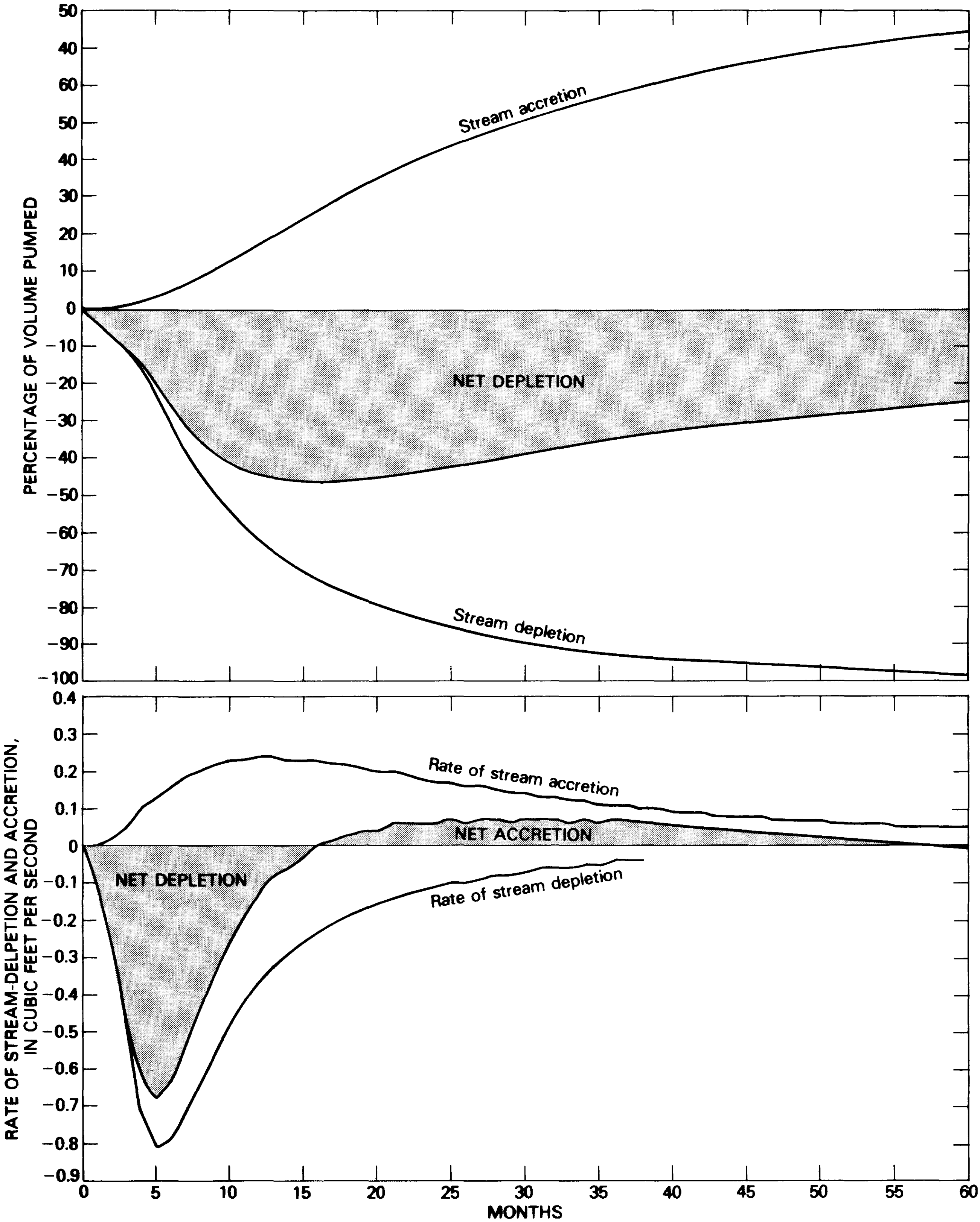

Figure 5. Stream accretion and depletion due to one 4-month recharge period.

The anticipated plan of augmentation, to operate for 4 months and then turn off for 8 months, was modeled using two separate simulations (one for pumpage and one for recharge). Figure 6 indicates that the rate of stream depletion due to pumpage would reach an equilibrium condition after 5 years of operation. The rate of accretion due to the recharge was not quite in equilibrium after 7 years. It is interesting to note that while the pumpage occurs for a 4-month period, the net stream accretion-depletion computed by superimposing the two curves during the seventh year shows a depletion for 6 months and an accretion for 6 months. Once the system reaches a cyclic equilibrium, the annual volume of stream depletion will exactly equal the annual volume of stream accretion. The pumpage was simulated to occur in months 1 to 4 of each modeled year, the resulting stream depletions occur in months 3 to 8. For planning purposes to avoid stream depletion during the critical low streamflow months of July and August, the simulation results indicate that the pumpage for the augmentation plan ought to occur no later than November through February.

REFERENCES

Bjorklund, L.J., and Brown, R. F., 1957, Geology and ground-water resources of the lower South Platte River valley between Hardin, Colorado, and Paxton, Nebraska: U.S. Geological Survey Water-Supply Paper 1378, 431 p.

Hurr, R. T., Schneider, P. A., and others, 1972, Hydrogeologic characteristics of the valley-fill aquifer in the Sterling reach of the South Platte River valley, Colorado: U.S. Geological Survey open-file report, 2 p., 6 Maps.

Lee, C. Y., Qazi, A. R., and Danielson, J. A., 1980, A digital model applied to ground-water recharge and management: Water Resources Bulletin, v. 16, no. 3, p. 514-521.

Skinner, M. M., 1963, Artificial ground-water recharge in the Prospect Valley area, Colorado: Colorado State University Agricultural Experiment Station, General Series 792, 89 p.

Trescott, P. C., 1973, Interactive-digital model for aquifer evaluation: U.S. Geological Survey open-file report, 63 p.

U.S. Department of Agriculture, 1974, Soil survey of Logan County, Colorado: Soil Conservation Service, 125 p.

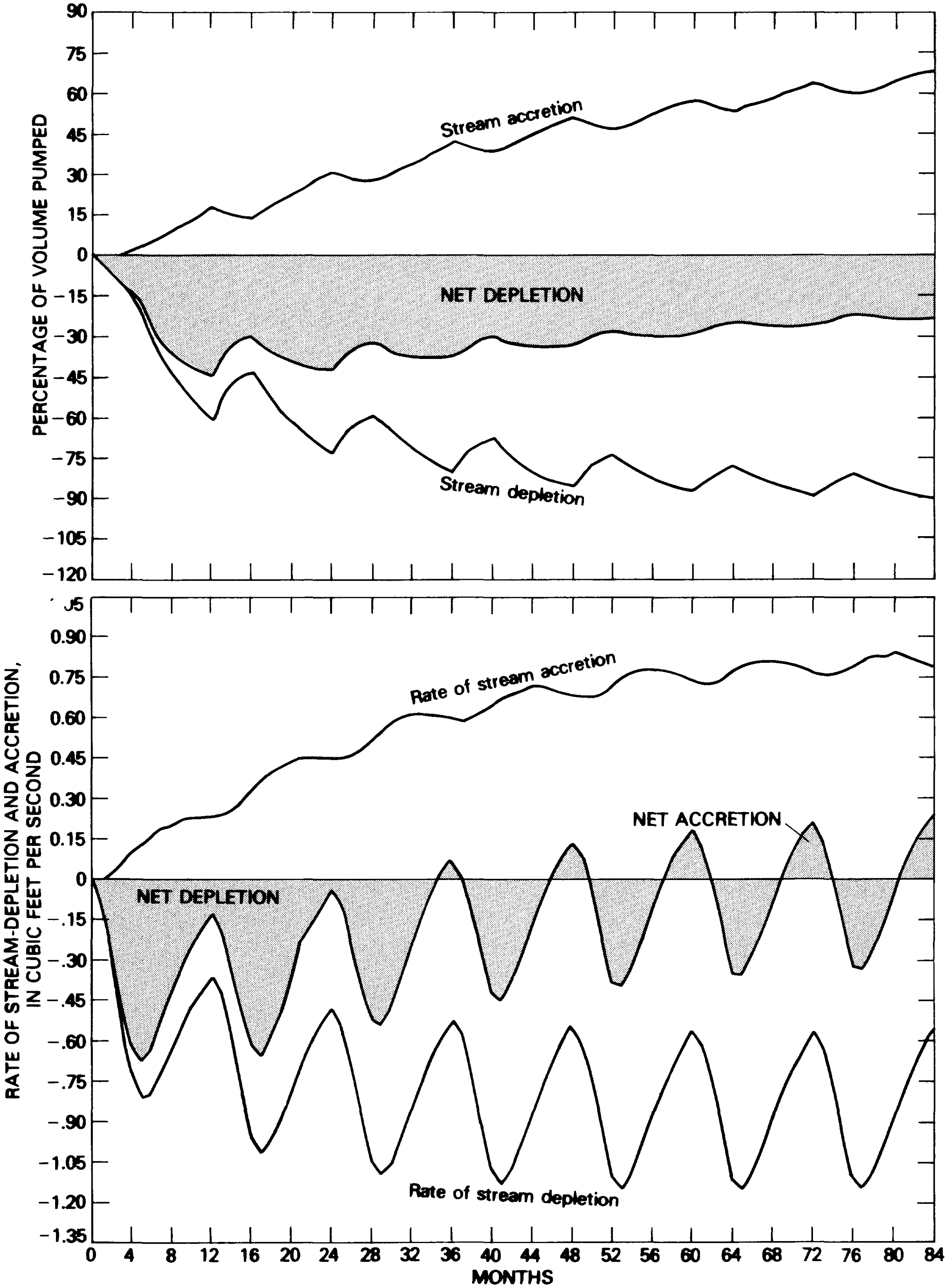

Figure 6. Stream accretion and depletion due to cyclic 4-month recharge periods.

SUPPLEMENTAL INFORMATION

The hydrologic system in the alluvial aquifer along the South Platte River is a complex interaction among recharge from irrigation applications and precipitation, ground-water pumpage, evapotranspiration, and the river. Developing a ground-water flow model to incorporate all of these features in a calibrated simulation was beyond the scope of this study. Instead, a simple difference model was used to simulate only the effects of the pumping well and artificial recharge on the river. All of the other stresses are ignored and the concept of superposition is assumed to apply.

In an unconfined aquifer system, transmissivity is a function of both hydraulic conductivity and saturated thickness; thus it is nonlinear. Superposition strictly applies only for a linear system, so the applicability of superposition to an unconfined aquifer is somewhat subjective, relative to how much saturated thickness changes.

The water-level changes monitored during this study at stock wells 722, 702, and 741 were all about 2 ft and are assumed to be unaffected by the artificial recharge. Two foot of change in that part of the aquifer represents a 5- to 10-percent change in saturated thickness. The greatest saturated thickness in the modeled area is 197 ft and the average thickness is about 100 ft. A 2-foot change in water level thus represents only about 2 percent change in transmissivity. Therefore, all of the unknown stresses, even if they are time variant, can be ignored, and superposition can be assumed to be applicable to simulate only the changes caused by the pumpage-recharge stress.

To better illustrate the effects of an aquifer stress on streamflow, the pumpage and artificial recharge were simulated separately with two distinct simulations (see figure 5 for example). The net effect on streamflow due to the simultaneous occurrence of the pumpage and the recharge was computed by adding the two separate responses. This technique again assumes that superposition is applicable under these highly stressed simulated conditions. To verify this assumption, another simulation was made with both stresses included.

The effects on streamflow for this simulation were within 1 percent of the results obtained by adding the effects of the two previous simulations. The main reason that the superposition does apply even in these highly stressed situations is the large areal change in transmissivity from the recharge area to the rest of the alluvial aquifer. When simulating only the pumpage, the maximum drawdown at the pumping well (which has an initial transmissivity of about 14,000 ft^2/d) was 23.7 ft. Drawdown at the recharge site (initial transmissivity of 60 ft^2/d) due to the pumpage was 0.0 ft. The maximum rise at the recharge site was 63.7 ft, when simulating only the artificial recharge. Water-level rise at the pumping well due to the recharge was 0.8 ft. For the simulation with pumpage and artificial recharge occurring simultaneously, the maximum rise at the recharge site was still 63.7 ft and maximum drawdown at the pumping well was slightly reduced to 21.1 ft.

Table 3.--*Driller's logs of four observation wells*

[Harold Canfield, Driller, Fort Morgan, Colo., 1979]

3		1		2		4	
Depth, in feet	Lithology	Depth, in feet	Lithology	Depth, in feet	Lithology	Depth, in feet	Lithology
0- 2	Sandy loam	0- 2	sandy loam	0- 2	sandy loam	0- 2	sandy loam
2- 60	Fine sand	2- 60	fine sand	2- 48	fine sand	2- 66	fine sand
60- 70	Fine sand, sand	60- 68	sand, fine sand	48- 62	fine sand, some gravel.	66- 74	gravel, sand, some boulders.
70- 75	Gravel, sand	68- 84	fine sand, some coarse gravel.	62- 87	coarse gravel, a few boulders.	74- 88	fine sand
75- 83	Some fine sand, sand.	84- 96	coarse gravel, a few boulders.	87- 93	fine sand, sand	88-100	clay, fine sand
83- 94	Coarse gravel	96-100	fine sand	93-103	some brule, sand	100-106	fine sand
94-117	Brule	100-111	gravel, a few boulders.	103-117	brule	106-117	brule, short strip of rock.